Results in Physics 4 (2014) 79–80

Contents lists available at ScienceDirect

Results in Physics

journal homepage: www.journals.elsevier.com/results-in-physics

Microarticle

Multiple loading and mechanical response of $Al_6O_{13}Si_2$–ZrO_2/Zn composite coating

O.S.I. Fayomi [a,b,*], A.P.I. Popoola [a], A.O. Inegbenebor [b]

[a] Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, P.M.B. X680, Pretoria, South Africa
[b] Department of Mechanical Engineering, Covenant University, P.M.B. 1023, Ota, Ogun State, Nigeria

ARTICLE INFO

Article history:
Received 26 April 2014
Accepted 20 May 2014
Available online 27 May 2014

Keywords:
Microstructure
Micro-hardness
Multiple loading
Mechanical responses

ABSTRACT

In this paper, $Al_6O_{13}Si_2$–ZrO_2/Zn composite coatings were prepared by electrolytic co-deposition technique on mild steel surface from sulfate bath. The coatings were investigated using (SEM), micro-hardness tester with MTR-300 dry abrasive wear. Results showed higher micro-hardness, good wear resistance and adhered microstructure. From mechanical response ZrO_2 composite has a strong effect on the interaction of the produced alloy.

1. Introduction

Ceramics composite deposition is an appreciated surface modification technology to obtain significant reinforced properties [1,2]. Their engineering relevance varied from wear resistance, increases in stiffness and high hardness properties. Promising option for zinc based alloy is the introduction of composite and nano-composite materials like TiO_2, SiO_2, ZrO_2, CNTs, WC, Al_2O_3, etc. [2–5]. However, there is a need to develop further suitable material where low reduction in weight to coating thickness is required with good mechanical properties. In view of the above properties, multiple ceramic properties of aluminum silicate and zirconium are considered since the wear and hardness characteristics are affected by particle loading. Therefore in this present study an attempt to investigate the mechanical response (wear and hardness behavior) of $Al_6O_{13}Si_2$–ZrO_2/Zn reinforced particulate on mild steel substrate and how its modification enhances the coating performance is considered.

2. Experimental procedure

Mild steel specimens of dimension (30 mm × 20 mm × 1 mm) sheet were used as substrate and zinc sheets of (40 mm × 30 mm × 2 mm) were prepared as anodes. The co-deposition process followed the same step as described in our previous studies [1,2]. The bath formulation is $ZnSO_4{\cdot}7H_2O$, 70 g/L, $Al_6O_{13}Si_2$ 15 g/L, ZrO_2 5–15 g/L, Boric acid 5 g/L, Glycine 5 g/L, Thiourea 5 g/L, Temp 40 °C, pH 4.5, Current density 1.0 A/cm^2, Time 15 min. The formulated design plan is as follows (1) Zn–15$Al_6O_{13}Si_2$ (2) Zn–15$Al_6O_{13}Si_2$–5ZrO_2 (3) Zn–15$Al_6O_{13}Si_2$–10ZrO_2 (4) Zn–15$Al_6O_{13}Si_2$–15ZrO_2.

3. Results and discussion

Fig. 1a and b shows the SEM structure of mild steel and Zn–$Al_6O_{13}Si_2$–ZrO_2 fabricated coating respectively with reference to Zn–15$Al_6O_{13}Si_2$–15ZrO_2. From Fig. 1b, compact microstructures with clear evolution of crystallite which are uniformly distributed along the interfaces were seen. The stability of the modified structure can be linked to the appropriate dissolving particulate and solid precipitation of the composite in zinc matrix in relation to the moderate deposition rate [1,3]. In the co-deposition process, $Al_6O_{13}Si_2$–ZrO_2 acts as a nucleation site which further helps to speedup zinc metal nucleation. The precipitation and absorption of particulate on metal matrix involves wt% Vol. particle in the electrolyte, dissolving capacity; good throwing power and Interpol of the individual elemental. The coating efficiencies from the varied matrix (Fig. 1c) were seen to follow the same trend of hardness and wear properties with Zn–15$Al_6O_{13}Si_2$–15ZrO_2 possessing highest coating efficiencies of about 93.73% followed by Zn–15$Al_6O_{13}Si_2$–10ZrO_2 with 73.21%. Zn–15$Al_6O_{13}Si_2$–5ZrO_2 58.44% and Zn–15$Al_6O_{13}Si_2$ without zirconium possesses low percentage with 37.7%.

* Corresponding author at: Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, P.M.B. X680, Pretoria, South Africa. Tel.: +27 719811277.

E-mail addresses: ojosundayfayomi3@gmail.com (O.S.I. Fayomi), popoolaapi@tut.ac.za (A.P.I. Popoola).

http://dx.doi.org/10.1016/j.rinp.2014.05.001
2211-3797/

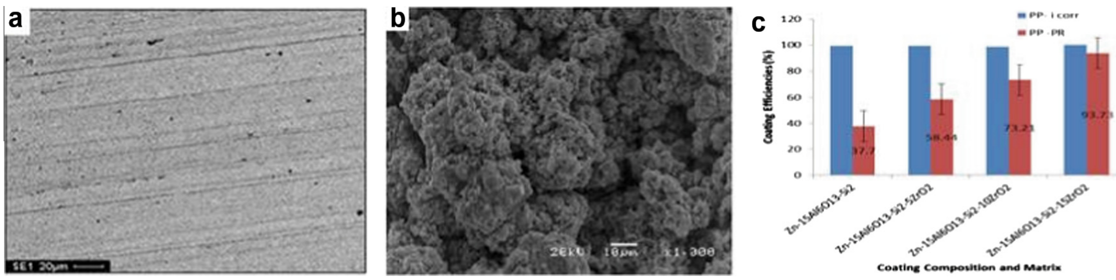

Fig. 1. SEM/EDS micrographs of [a] mild steel substrate [b] Zn–15$Al_6O_{13}Si_2$–ZrO_2 [c] composite coating efficiency.

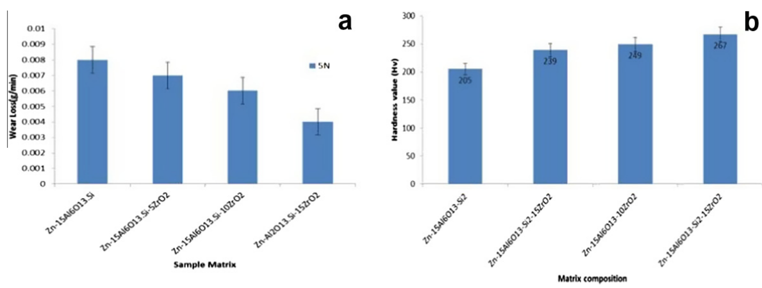

Fig. 2. Showing [a] hardness [b] wear resistance of fabricated nano-composite coating.

The effect of $Al_6O_{13}Si_2$–ZrO_2 on hardness and wear resistance properties can be seen from Fig. 2a and b that increasing ZrO_2 concentration at stable alumina silica in electrolyte lead to decrease in zinc dominates which is favorable to improve hardness and wear behavior. [3,4] also reported that it is expected that an increase in particulate concentration in electrolyte leads to an increase in the number of particulates in the deposited layer which is in line with the trend of hardness and wear properties observed in this study. Sometime the conditioning parameter in relation to the degree of additive impede also play a vital role in re-modification of the crystal orientation and surface texture of a deposited layer which in tune help in improving wear resistance.

4. Conclusions

A uniform distribution of Zn–$Al_6O_{13}Si_2$–ZrO_2 fabricated nanocomposite coating was produced with improved hardness and anti-wear resistance properties. 93% coating efficiency was attained.

Acknowledgements

This material is based upon work supported financially by the National Research Foundation Pretoria, South Africa. SERC is also appreciated for equipment support.

References

[1] Fayomi OSI, Popoola API. Res Chem Inter 2013;39:1354.
[2] Fayomi OSI, Popoola API, Abdulwahab M. J Ovonic Res 2013;9:123.
[3] Zheng HY, An MZ, Lu JF. Appl Surf Sci 2008;34:254–1650.
[4] Aziz M, Scheinder W, Plieth W. J Solid State Electrochem 2005;9:429–37.
[5] Fayomi OSI, Popoola API, Popoola OM. Inter J Electrochem Sci 2012;7:4860.